Main Domain of The Project : SOFTWARE

Proje Tematik Alanı : STEAM

Name of The Project : Simulation of population dynamics and its changes

Abstract

The main purpose of this project is to create a simulation that will allow to observe the reactions of the living creatures in different situations/conditions and how the populations will change under which conditions. While creating the simulation, a model created with various algorithms and codes with certain parameters related to ecosystem was used.

In this study, two different simulations were created. In the first study of simulation, as a sample species Maratus volans was chosen. Some key features and behaviors that will be the basis of simulation were selected. In the second simulation, as a living organism a fictional herbivore, and as a food/habitat a plant was assigned.

As a result, dynamics related to population biology, such as gene transfer, natural selection, interaction between living things, and the effects of the ecosystem, have been observed for generations.

It is thought that this project will have significant advantages such as making the natural environment editable on computer simulation with given parameters, helping scientists and researchers on simulating experiments that would normally take extremely long time and cost a lot, and the most importantly using the study as a pedagogical tool in education

Keywords: Simulation, Population, Bioinformatics, Genetic algorithm

Objective

It is very difficult or almost impossible and very costly to observe in real life how the researched creatures will react in different conditions and situations and how their populations will change under various conditions. Based on this challenging and limited situation, this project has been developed specifically for use in scientific studies. This project is a simulation study that enables us to observe how living things live, how they behave and how their population changes in various situations. The purpose of the study is to understand the basic dynamics of the living population and to create an observation environment for scientific studies by simulating the changes in the ecosystem. Also, with this study, the explanation of the complex problems related to population biology can be explained much more easily and practically.

Introduction

Living things are also subject to the laws of physics, as they are part of the world of physics, but it has not yet been possible to find natural laws similar to the law of gravity in biology or other branches of science such as economy, medicine, psychology which are subjects of livings behavior and dynamics, since even the simplest form of life contains highly complex features. Various mathematical or biological models have been created for the solution of this problem. For example, biological systems are tried to be understood and explained by models such as Mendel principles, Hardy-Weinberg hypothesis, and Prey-Predator relationship used to understand population dynamics.

Few things in the universe are as inspiring and mysterious as living systems. For example, "How can cell collections allow the human mind to think of complex, meaningful thoughts?" or "How do the various organic and inorganic actors in an ecosystem act? How do they interact to produce long-term stability?" or "How do embryos get their complex and elegant form over time?" These are deep mysteries. As researchers and biologists try to address these kinds of questions with increasing diligence, they need tools to help them learn about the complex interactions that occur in these systems, and one of the best tools available right now is computer simulations. (1).

In the early 1970s, Paulien Hogeweg and Ben Hesper began to use the term "Bioinformatics" in the sense of "investigation of information processes in biotic systems". (2). Bioinformatics, which is an interdisciplinary science branch today, is an interdisciplinary field that develops methods and software tools by combining many science branches such as software, mathematics, biology, logic, statistics, engineering to understand, analyze and interpret biological data. After the 2000s, bioinformatics studies focused mainly on genetics and molecular biology.

In this simulation study, first of all, a sample species was determined (Maratus volans). The current source information about the main topics to be covered in the simulation, Maratus volans and herbivores and Grass as Environment / Nutrient were studied. Then, some key features and behaviors that were the basis for the simulation were chosen and a simulation was created for Maratus volans. Later, a new simulation was designed with a fictitious herbivore which have modifiable features, and a plant as Food / Habitat. In this second simulation, different features such as movement, food search were added to the herbivorous creature, and the graphic and visual animation level of the simulation was also increased.

In the first simulation, observations can be made about the defined characteristics of this species (Maratus volans) and the behavior and change of its population. Ideas about natural selection can be obtained, population growth rate can be seen, and observations can be made about genetic transmission within the population.

In the second simulation, the level of representation was made more realistic by adding more complex features related to the environment / nutrients, time factor, two fictional species and living behaviors. Thus, the same concepts as in the first simulation can be observed and understood in a more complex simulation.

With this simulation modeling, an effective tool has been developed for a fast, safe, efficient solution of a subject that is still not fully understood in the real world, and an important method of analysis that is easily observed and understood is provided. Experimenting on a real population or ecosystem is almost impossible or impractical due to cost and time. This study, which I have done, can enable experiments on a digital environment related to live behavior, genetic transmission and population dynamics. With enrichment of animation in the second simulation, now the simulation serves as a more descriptive and pedagogical tool, more clearly represents the state of knowledge.

Method

First, an exemplary species was chosen. The Austrian peacock spider (Maratus volans) the creature itself and its behaviors were investigated from the scientific literature and a simulation sample was created using this creature. It was aimed to create a web-based interactive system using JavaScript, html and Css, all three in one. Thus, it was aimed to be accessible to the whole world. Program code was written using the Object-oriented programming method.

From real-life features of Maratus Volans:

- Female/Male
- Being Mom/Dad (Parent)
- Reproductivity (Reproduction desire)
- Reproductive behavior
- Strength
- Dance Talent
- Death

These specialities were selected. After the simulation codes were written and executed, the graphic codes were written and executed in order to better understand the issues to be observed with the graphics related to dependent / independent variables. Because of being practical and aesthetic, the graphic codes were prepared with the help of the open source library named chart.js. The graphics that we can detect the changes by entering the desired data have been added to the code.

This first simulation made an example and foundation. Later, the study was intended to be more sophisticated and an animated simulation consisting of two creatures were designed in one environment. A herbivore and a grass as habitat/nutriture was chosen

In addition to features of the first model:

- ❖ Hunger Level (if it is 60+ then creature starts looking for food,if it is bigger than 100+strength level then creature dies.)
- ❖ Searching for food
- ❖ Position in cartesian plane
- ❖ Direction-Movement (Ability to move in 8 direction . It chooses its direction itself and it could move at that direction)
- ❖ Intelligence (0-30)
- ❖ Charm ((Strength*0.4 + Intelligence x15)*100/490) (Formula explained in code itself)
- ❖ Sense range (its radius formula=> 5+Intelligence/3) (We can think of the sense range as an imaginary circle. Creature can only interact with creatures in this area. That means creatures in this area are also potential partners. User can see creatures sense are by dragging the mouse on the creature itself.)
- ❖ Birth rate (Possibility of giving birth to 1-14 puppies in one birth)
- ❖ Color (blue if it is male, pink if it female, yellow while reproducing)

  (These colors are used for a clear visual understanding.)

these features were added. In addition, other existing features in model 1 were also tried to be made more complex in terms of living individuals and population dynamics in order to increase the level of representation. For example, a link has been established between reproductive activity and age. In order for the herbivorous creature to breed, it must reach a certain age. Most importantly, it cannot mate with 1st degree relatives (Parents/child) in the population.

Grass was chosen as a tile of plant. The grass was designed as a food for a second living creature, as well as a habitat / environment. For the grass features such as:

- ❖ Growth rate
- ❖ Maximum growth level

were selected. Since the grass has environmental features, color codes were detailed to make it appear more clear in the simulation. The ground was created from a total of 300 tiles by default. If desired, the size of these tiles can be adjusted very easily. Thus, a more complex simulation where creatures can live by their own was prepared and executed. Graphic codes were written and run in order to better understand some of the issues that could be the subject of research and observation with the graphics related to dependent / independent variables. Chart.js library was once again preferred for graphics. Thus, the increases of variables over time are expressed visually.

Results

The Austrian Peacock spider, Maratus volans, is a very interesting creature with its behavior and features. It is a small spider species with a length of 3-5 millimeters and it is found in the southern Australian region. As can be seen in pictures 1 and 2, males can be distinguished from their females by tails (females do not have tails). (3) They can jump up to 20 times higher than their own size. "Volans" in Latin means flying, and in French it is the verb to fly "voler" from the same root, and so in taxonomy its name was given because it can jump up pretty high. Perhaps the most interesting feature of Maratus volans is the reproductive phase. Males show a dance before breeding to affect females, and if the females are not sufficiently affected, the females eat males; If it is affected, they mate and continue their generation. Even if the male spider could not affect the female, there is a possibility that it won't be eaten by the female but run away. (4), (5), (6).

Picture 1. (3)

Picture 2. (3)

In the Maratus Volans simulation, it was paid attention to use some basic features of the creature. In the simulation, male primarily finds a partner as in real life. For reproductive activity, the level of talent of males to dance should be equal to or greater than the level of females desire to reproduce. If the partner's desire to reproduce is higher than the male's ability to dance, the male is either fleeing or dying according to the power level of the male and female. In the simulation, Female / Male can be distinguished with features such as dance ability, breeding desire, color and tail image.We can observe gene transfer in generations in the population as a result of reproductive activity. We can observe the death which occurred as a result of determined life span or eaten by the females, and monitor its impact on the population. As the generation increases, we can observe both the population increases and the male individuals with high dance ability survive in the population (natural selection).

In the second simulation, 4 different status / phases of Grass, which is modeled as habitat/nutrient, can be seen as 0, I, II, III, IV.

- **0th Stage** The driest form of the medium. Completely dry soil with no grass that can be eaten or consumed
- **1st Stage** slightly grown, consumable
- **2nd. Stage** has grown even more and only some of it has been consumed.
- **3rd. Stage** We can observe the maximum grown up and mature form.

The grass can be eaten by the herbivores on top it if it is grown, and when grass is consumed, it grows fast or slow depending on the parameters defined for its gene. When the simulation starts, the population of herbivores is randomly generated. The herbivore can move in 8 different directions, it selects them itself and it can move in the direction it chooses. Depending on its level of hunger (if it is above 60) it starts searching for food. It eats when it finds the food; if it cannot find the food and its level of hunger becomes more than 100+it's value of strength, it dies. Every creature has a variable, defined as a sense radius (5+it's value of intelligence/3), and this radius provides a circular vision field. It can interact with other creatures in the field of view. Females entering the field of view of male creatures can be potential partners of the herbivore. The charm value of male individuals ((Strength * 0.4 + Intelligence x15) * 100/490) determines the probability of reproduction. If the female,

- is in the vision of the male,
- is not a former partner,
- is not a first-degree relative (child or partner),

then we can observe the reproduction with the probability determined by the charm of the male. The number of puppies per birth is between 1 and 14 (calculated from rabbits as an example). Intelligence (first 0-20 then later with gene transfer or 0-30), which determines the characteristics such as charm, vision, is determined randomly at the very beginning of the simulation but is genetically transferred to the next generations in the population with a probability of 80% (can be changed as desired).

Observations can be made on many parameters. In this project, we can easily see the impact of the environment on the population. As the number of grass decreases, the increase in the population decreases. The growth rate of grass also affects the population increase in direct proportion. Also, the charm value of living things are directly proportional to their intelligence and strength. As a result, we can estimate that the more intelligent and stronger are more likely to continue their generation than others. In simulation, we can see that intelligence and power averages increase as time passes.

Explanation of Codes

The explanations of the codes were indicated in comment blocks.

2nd simulation codes

Conclusion and Discussion

Of course, when we look at nature and real life, we know that there are almost countless factors, variables, and very fine adjustments. There are really countless processes and factors such as temperature, humidity level, diseases, disasters, consciousness, and of course it is almost impossible to simulate and regulate this by transferring it to a computer program. Even if very important universities and institutes are working on this subject, we know that simulations, which we can call completely realistic, are not currently available in the world. At least we can say this for complex living things. Therefore, we cannot say that it is completely realistic and perfect, but it can be stated that this project is a very important step. We can prove this with the observations and conclusions we make when we run the program.

Here is a chapter of an article also supporting the idea of even if a model is not perfect still it can be very utile. (7)

After the significant part of the project was completed, project were shared with students, individuals at various educational levels and experts in informatics and biology. Their opinions and criticisms were received. Frankly, everyone found the project very impressive and meaningful. The most liked part was that it was very easy to understand.

Suggestions

First, the user interface can be added to the project.

In the later phase of the project, it may be possible to sophisticate the behavior and characteristics of the creatures.Also more living and ambient features can be added. For example, there may be watery areas or different climate models can be added to the simulation. As the project progresses, the representation level of the model will increase and get closer to real life.

It is possible to add more factors, variables and further optimize this work. Optimization is very important because as the code increases and information and data are added, the simulation may become vulnerable to code errors or slow down. Therefore, in order to improve this work, it is necessary to add much more data and also to optimize the code much faster.

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